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Final Report

Investigation of Glass Fibers as Reinforcement for Prestressing Concrete

Contract No. NBy 8996

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Introduction

This project was directed by the late W.Mack Angas (Vice Admiral, CEC, USN, Ret.) and since his passing the Department of Civil Engineering has found no one to continue his dedicated efforts. In general the project was a feasibility study which examined the possibility of harnessing the tensile strength available in small diameter glass fibers for carrying the tension forces in prestressed concrete.

The work was financed by the Bureau of Yards and Docks, Department of the Navy under contract NBy 8996 and the Princeton University Eugene Higgins Fund. The investigation usually involved one graduate student plus the efforts of Admiral Angas and at times other faculty members. The efforts of the faculty members, except for traveling expenses, cost the project nothing.

The investigation was initiated in September 1951 and the written documents listed below have resulted. At least one copy of each is available in the Princeton University Library.

"Report on the Preliminary Investigation on the Feasibility of Using Fiber Glass for Prestressing Concrete," Ivan Rubinsky, August 1951.

"Investigation of the Feasibility of Using Fiber Glass for Prestressing Concrete," Kenneth W. Keane, Master Thesis, June 1952.

"Progress Report for Period Ending April 30, 1953."

"An Investigation of the Effects of Repetitive Loading on Fiber Glass Rods in Prestressed Concrete Construction," John M. Weis, Master Thesis, June 1954.

"The Development of Fiber Glass Reinforced Plastic Rods," Alexander Surko, Jr., Master Thesis, June 1955.

"Final Report - Investigation of Glass Fibers as Reinforcement for Prestressing Concrete," undated (about June 1955)

"Report on Further Investigation Concerning the Feasibility of the Use of Fiber Glass Tendons in Prestressed Concrete Construction," Frank J. Maguire, III, Master Thesis, September 1960.

Conclusions

The investigations carried on during the course of this research project reveal the following conclusions:

1. Fiber glass rods do not show promise for use as tendons for post-tensioning concrete structures.
2. Fiber glass rods do show promise for use as tendons for pre-tensioning concrete structures by bonding the rods to the concrete.
3. Fiber glass rods having an ultimate strength in excess of 200,000 psi. based on gross cross-sectional area and a safe working stress of approximately 100,000 psi. can be fabricated.
4. Fiber glass rods show definite promise of resisting unusual corrosion conditions but exposure tests will be necessary.

General

The first investigator connected with the project was Ivan A. Rubinsky. At an early stage he concluded that glass fibers used as ordinary reinforcement in place of reinforcing steel were not feasible

because of the low modulus of elasticity of glass. He then suggested its use as tendons for prestressing concrete. In this case the low modulus of elasticity of the glass is an advantage since the lower it is the less will be the effect of shrinkage and plastic flow of the concrete on the stresses in the glass tendons.

Mr. Rubinsky experimented with glass fibers, fiber glass cords and finally with fiber glass rods. The rods were manufactured in a way similar to those used for fishing rods. This type of material retained some of the strength qualities of the glass fibers and in addition protected them from the weakening effects of adsorbed water and the chemical action of the alkalies in the cement. At this point it was decided to discard the study of fiber glass cords and concentrate on the rods.

A 1/4" diameter rod was chosen for study. This appeared to be a reasonable size for laboratory work and a manufacturer was willing to supply it. Much of the subsequent effort involved this size of fiber glass rod.

Mr. Rubinsky's work is recorded in a "Report on the Preliminary Investigations on the Feasibility of Using Fiber Glass for Prestressing Concrete," Ivan Rubinsky, August 1951.

The next investigator was Mr. Kenneth W. Keane. He attempted to develop a means of determining the tensile strength of the fiber glass rod. This was considerably more difficult than was anticipated at that time. Since glass is completely brittle, i.e. it breaks without any ductile action, it is impossible to create a stress concentration without causing failure at that point. A large number of devices were tried but failure continued to occur at the end connection. However, strength tests were made which essentially developed the strength of the rod.

Mr. Keane's work is recorded in a master's degree thesis: "Investigation of the Feasibility of Using Fiber Glass for Prestressing Concrete," Kenneth W. Keane, June 1952.

The next investigator was Mr. John M. Weis. The first year he developed an end connection which consisted of splaying the end of the rod in standard cable socket and filling it with epoxy. This was considered fairly successful at the time but failures still occurred in the end connection.

Concurrently with this work a prestressing frame was designed in which small pretensioned beams could be built. In this way the strength of the rod could be developed through bond and thus not have to depend on an end connection for more than the pre-tensioning force. Testing to failure of the pre-tensioned beams indicated that the ultimate strength of the rods was similar to the strength obtained by a simple tension test with end connections. This information was very good proof that the strength of the rods was not as high as expected by the investigators.

It was then decided that the strength of the rod was not satisfactory and that efforts to improve it were in order. Manufacturers were contacted and assistance was requested but in most cases the manufacturers claimed that their product was strong enough for its current use.

While the possibilities of imporving the strength of the rod were being explored Mr. Weis fabricated a group of small pre-tensioned beams and tested them under repeated loading conditions.

The work done between June 1952 and June 1954 is recorded by the following:

"Progress Report for Period Ending June 30, 1953."

"An Investigation of the Effects of Repeated Loadings on Fiber Glass Rods in Prestressed Concrete Construction," John M. Weis, - a master's degree thesis - June 1954.

The next investigator, Alexander Surko, Jr., attempted to develop a stronger fiber glass rod. Various types of glass fibers were purchased and

rods designed as test specimens were fabricated in the laboratory. Although the laboratory fabrication was a very uneconomical process, it was shown that stronger rods could be made. The strengths of the specimens in most cases practically doubled those obtained from the commercially available rods.

Mr. Surko's work is recorded in a master's degree thesis: "The Development of Fiber Glass Reinforced Plastic Rods," June 1955.

At this time it was decided to reduce the laboratory investigation and attempt to induce commercial interests in improving the strength of the fiber glass rods. A report was written by Mr. Surko and Admiral Angas which unfortunately was not dated. Since it appeared that the project was essentially to terminate the report was called "Final Report - Investigation of Glass Fibers as Reinforcement for Prestressing Concrete," written about June 1955.

However, the project continued and the commercial production of stronger rods was urged. Suggestions for improved fabriaction were made and samples were purchased and tested. In 1959 Mr. Frank J. Maguire, III chose for his thesis the correlation of the data. While doing this he also made several tests of his own where it was attempted to produce an improved connection.

Mr. Maguire's work is recorded in a master's degree thesis: "Report on Further Investigation Concerning the Feasibility of the Use of Fiber Glass Tendons in Prestressed Concrete Construction," September 1960.

Admiral Angas died on December 12, 1960, and the loss of his interest and direction was fatal to the project. Some testing of commercially purchased rods continued and several pre-tensioned prestressed concrete beams were fabricated under the direction of Professor Billington who was then newly appointed to the teaching staff. Other work requirements

did not permit him to continue and no other personnel was available. For these reasons it became obvious that this department could no longer do justice to the work and no money was spent after June 1961.

Respectfully submitted,

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